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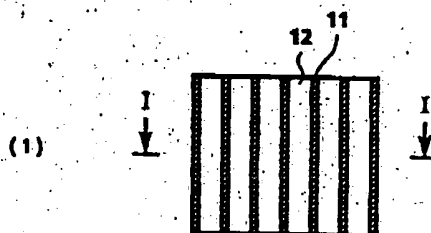
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(54) Stimulable phosphor sheet

(57) A stimulable phosphor sheet for a radiation image recording and reproducing method comprising the steps of recording a radiation image as a latent image, irradiating the latent image with stimulating rays to release stimulated emission, and electrically processing the emission to reproduce the radiation image, has partitions that divide the phosphor sheet on its plane to give plural sections, and stimulable phosphor-incorporated areas in the sections, wherein the phosphor-incorporated areas have a light-scattering length of 20 to 100 μm and a light-absorption length of 1,000 μm or longer, while the partitions have a light-scattering length of 0.05 to 20 μm and a light-absorption length of 1,000 μm or longer, under the condition that a ratio of the light-scattering length of the phosphor-incorporated areas to that of the partitions is 3.0 or more.

FIG. 1



Description

FIELD OF THE INVENTION

5 [0001] The present invention relates to a stimuable phosphor sheet employable in a radiation image recording and reproducing method utilizing stimulated emission produced by a stimuable phosphor.

BACKGROUND OF THE INVENTION

10 [0002] As a method replacing a conventional radiography using a combination of a radiographic film and radiographic intensifying screens, a radiation image recording and reproducing method utilizing a stimuable phosphor was proposed and is practically employed. The method employs a stimuable phosphor sheet comprising a stimuable phosphor layer (i.e., radiation image storage panel) provided on a support, and the procedure of the method comprises the steps of causing the stimuable phosphor of the stimuable phosphor sheet to absorb radiation energy having passed
15 through an object or having radiated from an object; sequentially exciting the stimuable phosphor with an electromagnetic wave such as visible light or infrared rays (hereinafter referred to as "stimulating rays") to release the radiation energy stored in the phosphor as light emission (i.e., stimulated emission); photoelectrically detecting the emitted light to obtain electric signals; and reproducing the radiation image of the object as a visible image from the electric signals. The stimuable phosphor sheet thus processed is subjected to a step for erasing a radiation image remaining therein, and then stored for the next recording and reproducing procedure. Thus, the stimuable phosphor sheet can be repeatedly employed.

[0003] In general, a support and a protective film are provided on the top and bottom surfaces of the stimuable phosphor sheet, respectively. The stimuable phosphor sheet generally comprises a binder and stimuable phosphor particles dispersed therein, but it may consist of agglomerated phosphor without binder. The stimuable phosphor sheet containing no binder can be formed by the deposition process or firing process. Further, the stimuable phosphor sheet comprising agglomerated phosphor soaked with a polymer is also known. For the aforementioned method, any types of the stimuable phosphor sheets are employable.

[0004] The radiation image recording and reproducing method is often used in radiography for medical diagnosis. In that case, it is especially desired to obtain a radiation image of high quality (particularly, high sharpness for high resolution) by applying a small dose of radiation. Therefore, the stimuable phosphor sheet is required to have high sensitivity and to provide a radiation image of high quality.

[0005] The sharpness of radiation image is mainly affected by diffusion or scattering of the stimulating rays in the stimuable phosphor sheet. The procedure for reading the latent image comprises the steps of sequentially scanning a beam of the stimulating rays on the surface of the stimuable phosphor sheet to induce the stimulated emission, and successively detecting the stimulated emission. If the stimulating rays diffuse or scatter (horizontally in particular) on the plane of the phosphor sheet, it excites the phosphor not only at the target spot but also in its periphery. Consequently, the stimulated emission emitted from the target position is collected together with that from the periphery. Such contamination of the emissions impairs the sharpness of the resulting radiation image.

[0006] For avoiding the diffusion or scattering of the stimulating rays, it has been proposed to divide the plane of the stimuable phosphor sheet into small sections (cells) with a partition capable of reflecting the stimulating rays.

[0007] Japanese Patent Provisional Publication No. 59-202100 discloses a stimuable phosphor sheet having a honey-comb structure consisting of many small cells filled with a stimuable phosphor. The phosphor sheet comprises a substrate and a stimuable phosphor layer provided thereon, and the honey-comb structure sectioned with a partition is further provided on the phosphor layer.

45 [0008] Japanese Patent Provisional Publication No. 62-36599 discloses a stimuable phosphor sheet employing a support provided with many hollows regularly arranged on one surface. The hollows are filled with a stimuable phosphor, and the ratio of depth to diameter of each hollow is 3.5 or more.

[0009] Japanese Patent Provisional Publication No. 2-129600 discloses a stimuable phosphor sheet (i.e., radiation image storage panel) employing a support plate having many holes vertically bored and filled with a stimuable phosphor.

50 [0010] In these known stimuable phosphor sheets employing a support or substrate provided with many cells (i.e., holes or hollows) incorporated with a stimuable phosphor, a part of the support or substrate serves as a partition for reflecting the stimulating rays to prevent diffusion of the stimulating rays.

[0011] In the stimuable phosphor sheet having the cells, the partition preferably has a small thickness so that the stimuable phosphor-incorporated area is formed as large as possible. However, it is necessary to incorporate a light-absorbing material into a partition if the partition is made to have a small thickness, maintaining the light-intercepting property. The incorporation of the light-absorbing material into the partition decreases efficiency of recovery of the stimulated emission. If the thickness of the partition is increased, the amount of stimuable phosphor which can be incorpo-

rated into the stimuable phosphor sheet decreases and hence an enough amount of radiation energy is absorbed by the phosphor sheet. It can be considered to increase the thickness of the stimuable phosphor layer so as to incorporate an enough amount of the stimuable phosphor. However, the radiation energy hardly reaches the stimuable phosphor in the bottom portion in the phosphor layer having the increased thickness. Moreover, the stimulated emission produced in the bottom portion is not efficiently recovered from the surface of the stimuable phosphor sheet. For these reasons, there is not known a stimuable phosphor sheet that has a cell structure and gives a reproduced radiation image of satisfactorily high quality.

[0012] Accordingly, the present invention has an object to provide a stimuable phosphor sheet which gives a reproduced radiation image of high quality, particularly, in its sharpness.

[0013] The invention further has an object to provide a stimuable phosphor sheet that has high sensitivity and gives a reproduced radiation image of high quality, particularly, in its sharpness.

SUMMARY OF THE INVENTION

[0014] The present inventors have made studies on the cell structure of the stimuable phosphor sheet and discovered that the partition should have a high reflectance to the stimulating rays by shortening its light-scattering length and should have a low absorbance for the stimulated emission by prolonging its light-absorption length for the stimulated emission, so that the diffusion of the stimulating rays on the plane of the phosphor sheet can be efficiently reduced to increase sharpness of the obtained radiation image and the decrease of emission efficiency can be effectively obviated by suppressing absorption of the stimulating rays as well as the stimulated emission. The inventors have further discovered that the stimuable phosphor-incorporated area should show a high transmittance for the stimulating rays by prolonging its light-scattering length and should have a low light-absorbance for the stimulated emission by prolonging the light-absorption length for the stimulated emission, so that the stimulating rays can reach the deep area of the stimuable phosphor sheet and the stimulated emission produced in the deep area can be efficiently recovered. Thus designed stimuable phosphor sheet gives a reproduced radiation image of high quality. Moreover, the stimuable phosphor sheet which has such characteristics and a large thickness gives a reproduced radiation image of increased high quality, increasing its sensitivity, namely, a ratio of absorption of radiation energy.

[0015] The invention resides in a stimuable phosphor sheet for a radiation image recording and reproducing method comprising the steps of recording a radiation image as a latent image, irradiating the latent image with stimulating rays to release stimulated emission, and electrically processing the emission to reproduce the radiation image, comprising partitions that divide the phosphor sheet on its plane to give plural sections, and stimuable phosphor-incorporated areas in the sections wherein the stimuable phosphor-incorporated areas have a light-scattering length of 20 to 100 μm and a light-absorption length of 1,000 μm or longer, while the partitions have a light-scattering length of 0.05 to 20 μm and a light-absorption length of 1,000 μm or longer, under the condition that a ratio of the light-scattering length of the stimuable phosphor-incorporated areas to that of the partitions is 3.0 or more.

[0016] The invention further resides in a radiation image recording and reproducing method comprising the steps of recording on a stimuable phosphor sheet of the invention a radiation image as a latent image, irradiating the latent image with stimulating rays to release stimulated emission, and electrically processing the emission to reproduce the radiation image.

[0017] In the present invention, the term of light-scattering length indicates a mean distance in which a light travels straight until it is scattered, and therefore a shorter light-scattering length means that the phosphor layer or partition highly scatters a light. The term of light-absorption length indicates a mean free distance in which the stimulated emission is absorbed, and therefore a longer light-absorption length means that the phosphor layer or partition shows a lower light absorbance.

[0018] The light-scattering length and light-absorption length can be determined by calculation according to Kubelka-Munk theory. The details are given below.

[0019] First, three or more film samples are prepared. Each film sample has a different thickness, but made of the same material of the partition or the stimuable phosphor-incorporated area. The thickness a (μm) and the diffuse transmittance (%) of each film sample are then measured. The diffuse transmittance (%) can be measured by means of a spectrophotometer equipped with an integrating sphere. In the below-described examples of the present specification, an automatic recording spectrophotometer (U-3210, manufactured by HITACHI, Ltd.) equipped with an integrating sphere of 150 ϕ (150-0910) is used. The diffuse transmittance should be measured at a wavelength corresponding to the maximum peak (for instance, 600 nm) of the stimulation spectrum of the stimuable phosphor in the stimuable phosphor-incorporated area, or at a wavelength corresponding to the maximum peak (for instance, 400 nm) of the stimulated emission spectrum of the stimuable phosphor.

[0020] From the thickness (μm) and the diffuse transmittance (%) obtained in the above-mentioned measurements, the light-scattering length and light-absorption length are calculated by the below-mentioned formulas which are derived from Kubelka-Munk theory. For instance, the formulas can be easily derived, under the boundary condition of

the diffuse transmittance (%), from the formulas 5.1.12 to 5.1.15 described in "Keikotai Handbook [in Japanese, Handbook of phosphor]", published by Ohm-sha, 1987, pp.403.

[0021] In the beginning, light strength distribution $I(Z)$ is calculated using a thickness ($d \mu\text{m}$) of a phosphor sheet, a reflectance (d_r) of the reflection sheet, a light-scattering length ($1/\alpha$) of the sample film, and a light-absorption length ($1/\beta$) of the sample film. $I(Z)$ is then divided into $i(Z)$ for a component advancing from the upper surface of the phosphor sheet and $j(z)$ for a component advancing from the lower surface to the upper surface of the phosphor sheet. Therefore, the relationship is written as follows:

$$I(Z) = i(Z) + j(Z)$$

[0022] Increase or decrease of strength by scattering/absorption at an optional depth in a film having a small thickness dz can be obtained by solving the following simultaneous differential equations according to Kubeluka-Munk theory:

$$di/dz = -(\beta + \alpha)i + \alpha j \quad (1)$$

$$dj/dz = (\beta + \alpha)j - \alpha i \quad (2)$$

[0023] Assuming the conditions of $\gamma^2 = \beta(\beta + 2\alpha)$, $\xi = (\alpha + \beta - \gamma)/\alpha$, $\eta = (\alpha + \beta + \gamma)/\alpha$, and K and L for integration constants, the general solutions for i and j of the simultaneous equations are described below:

$$i(z) = Ke^{-\gamma z} + Le^{\gamma z}$$

$$j(z) = K\xi e^{-\gamma z} + L\eta e^{\gamma z}$$

[0024] The light transmittance T of a phosphor sheet having a thickness d is described as follows:

$$T = i(d)/i(0)$$

[0025] Assuming that there is no returning light (namely, $j(d) = 0$), a light transmittance T of the phosphor sheet alone is calculated in terms of a function of the thickness d , as follows:

$$T(d) = (\eta - \xi) / (\eta e^{\gamma d} - \xi e^{-\gamma d}) \quad (3)$$

[0026] The light transmittance data measured by means of a spectrophotometer and data of the phosphor sheet are processed according to the equation (3) and fitted by a method of least squares, to give an optimum $1/\alpha$ and $1/\beta$. Thus, the light-scattering length as well as the light-absorption length are determined.

[0027] The preferred stimuable phosphor sheets of the invention are given below.

- (1) The stimuable phosphor-incorporated areas comprise stimuable phosphor particles and a binder.
- (2) The stimuable phosphor particles in the stimuable phosphor-incorporated areas have a volume in the range of 40% to 90% of the phosphor-incorporated area, and the phosphor-incorporated areas have a void volume of 0 to 20%.
- (3) The partitions of the stimuable phosphor sheet comprise low light-absorbing fine particles and a binder.
- (4) The low light-absorbing fine particles in the partitions have a volume in the range of 30% to 90% of the partition.
- (5) The low light-absorbing fine particles have a particle size of 0.01 to 5.0 μm .
- (6) The low light-absorbing fine particles are fine particles of alumina.
- (7) The partitions of the stimuable phosphor sheet further comprise voids.
- (8) The partitions of the stimuable phosphor sheet further comprise voids in a volume of 10% to 70%.
- (9) A ratio of refractive index of the low light-absorbing fine particles to that of the voids in the partitions is in the range of 1.1 to 3.0.
- (10) The partitions further comprise stimuable phosphor particles.
- (11) The partitions are dyed with a coloring material which absorbs the stimulating rays, while absorbs no stimulated emission.
- (12) The stimuable phosphor sheet has a thickness in the range of 50 to 1,500 μm .

BRIEF DESCRIPTION OF DRAWINGS

[0028]

Fig. 1-(1) is a schematic plane view of a stimuable phosphor sheet of the invention, and Fig. 1-(2) is a section view of the stimuable phosphor sheet of Fig. 1-(1) taken along I-I line.

Fig. 2 is an enlarged view of the stimuable phosphor-incorporated areas of the stimuable phosphor sheet of the invention.

Fig. 3 is an enlarged view of the partition of the stimuable phosphor sheet of the invention.

Figs. 4-(1), -(2), and -(3) are plane views showing different combinations of the stimuable phosphor-incorporated areas and the partition of the stimuable phosphor sheet of the invention.

Figs. 5-(1), -(2), and -(3) are sectional views showing different embodiments of the stimuable phosphor sheet of the invention.

Fig. 6 graphically indicates a relationship of the thickness of the stimuable phosphor sheet and the luminance (in terms of relative value) of the stimulated emission in the case that the partition has a thickness of 30 μm .

Fig. 7 graphically indicates a relationship of the thickness of the stimuable phosphor sheet and the sharpness (in terms of $2\text{lp} \cdot \text{CTF}$) in the case that the partition has a thickness of 30 μm .

Fig. 8 graphically indicates a relationship of the light-scattering length of the partition and the sharpness (in terms of $2\text{lp} \cdot \text{CTF}$) in the case that the stimuable phosphor-incorporated area has a light-scattering length of 66 μm and the stimuable phosphor sheet has a thickness of 40 μm .

Fig. 9 graphically indicates a relationship of the light-scattering length of the partition and the luminance (in terms of relative value) of the stimulated emission in the case that the partition has a light-scattering length of 4 μm and a thickness of 30 μm .

DETAILED DESCRIPTION OF THE INVENTION

[0029] The stimuable phosphor sheet having a cell structure according to the invention which has a combination of the partitions showing a short light-scattering length for stimulating rays and a long light-absorption length for stimulated emission and the stimuable phosphor-incorporated area showing a long light-scattering length for stimulating rays and a long light-absorption length for stimulated emission reproduces a radiation image of high sharpness, because diffusion of the stimulating rays on the plane of the phosphor sheet is effectively reduced. Further, the stimulating rays can reach a deep portion of the stimuable phosphor-incorporated area and the stimulated emission produced in the deep portion is efficiently recovered, because absorption of the stimulating rays and the stimulated emission by the partition is reduced. Accordingly, the total amount of recoverable stimulated emission is remarkably increased. Further, if the thickness of stimuable phosphor sheet is increased, the stimuable phosphor sheet can absorb an increased amount of the applied radiation such as X-rays, so that a radiation image of higher quality can be reproduced.

[0030] Therefore, the stimuable phosphor sheet of the invention is favorably employable particularly in radiography for clinical examination and for recording microscopic images.

[0031] The stimuable phosphor sheet of the invention is designed for the use in the aforementioned radiation image recording and reproducing method and is characterized by basically comprising partitions dividing the plane of the stimuable phosphor sheet into sections and stimuable phosphor-incorporated areas sectioned with that partitions. Each of the partitions and stimuable phosphor-incorporated areas has a light-scattering length and a light-absorption length specified above.

[0032] The stimuable phosphor sheet of the invention which has the partitions and stimuable phosphor-incorporated areas is described by referring to the attached drawings.

[0033] Fig. 1-(1) is a schematic plane view of a stimuable phosphor sheet 10 according to the invention. Fig. 1-(2) is a section view of the stimuable phosphor sheet 10 of Fig. 1-(1) taken along I-I line. In Figs. 1-(1) and 1-(2), the shaded portions represent partitions 11, and the areas enclosed with the partitions 11 represent the stimuable phosphor-incorporated areas 12. The stimuable phosphor sheet preferably has a thickness of 50 to 1,500 μm , so as to increase the radiation energy absorption efficiency. The stimuable phosphor-incorporated areas preferably have a mean size (of length and width on the plane) in the range of 5 to 300 μm , so as to accomplish an appropriate resolution and good image quality. The partitions preferably have a mean width in a range of 0.5 to 50 μm . A ratio of S_p (total surface area of all stimuable phosphor-incorporated areas) to S (total surface area of the stimuable phosphor sheet), namely S_p/S (i.e., ratio of opening area), preferably is 0.40 to 0.98 (40% to 98%).

[0034] In the stimuable phosphor sheet of the invention, the stimuable phosphor-incorporated area 12 shows a light-scattering length ($1/\alpha_1$) in the range of 20 to 100 μm for the stimulating rays and a light-absorption length ($1/\beta_1$) of 1,000 μm or more for the stimulated emission. The partition 11 shows a light-scattering length ($1/\alpha_2$) in the range of 0.05 to 20 μm for the stimulating rays and a light-absorption length ($1/\beta_2$) of 1,000 μm or more for the stimulated emission.

Further, a ratio of the light-scattering length of the stimuable phosphor-incorporated area to the light-scattering length of the partition, namely $(1/\alpha_1)/(1/\alpha_2)$, is 3.0 or more.

[0035] The stimuable phosphor-incorporated area 12 preferably comprises stimuable phosphor particles and a binder in which the phosphor particles are dispersed and combined. More preferably, the phosphor-incorporated area 12 comprises stimuable phosphor particles, a binder, and voids (i.e., voids of air).

[0036] Fig. 2 is an enlarged view of the stimuable phosphor-incorporated area 12. The phosphor-incorporated area 12 comprises stimuable phosphor particles 13, voids 14, and a binder 15. A ratio of the volume (V_{p1}) of stimuable phosphor particles 13 to the volume (V_1) of stimuable phosphor-incorporated area 12, namely V_{p1}/V_1 , preferably is in the range of 0.40 to 0.95 (i.e., 40% to 95%). A ratio of the volume (V_{v1}) of voids 14 to the volume (V_1) of stimuable phosphor-incorporated area 12, namely V_{v1}/V_1 , preferably is in the range of 0 to 0.20 (i.e., 0% to 20%). The stimuable phosphor particles 13 preferably have a mean diameter of 1 to 10 μm .

[0037] The partition 11 preferably comprises low light-absorbing fine particles and a polymer binder in which the particles are dispersed and supported. More preferably, the partition 11 comprises low light-absorbing fine particles, voids, and a polymer binder.

[0038] Fig. 3 is an enlarged view of the partition 11. The partition 11 comprises low light-absorbing fine particles 16, voids 17, and a polymer binder 18. A ratio of the volume (V_{f2}) of low light-absorbing fine particles 16 to the volume (V_2) of partition 11, namely V_{f2}/V_2 , preferably is in the range of 0.30 to 0.90 (i.e., 30% to 90%). A ratio of the volume (V_{v2}) of voids 17 to the volume (V_2) of partition 11, namely V_{v2}/V_2 , preferably is in the range of 0.10 to 0.70 (i.e., 10% to 70%). The low light-absorbing fine particles 16 preferably have a mean diameter of 0.01 to 5.0 μm . The low light-absorbing fine particles 16 preferably have a ratio of a refractive index K_f of the fine particles 16 to a refractive index K_a of voids 17, namely K_f/K_a , preferably is in the range of 1.1 to 3.0.

[0039] The cell structure of the stimuable phosphor sheet of the invention may be a one-dimensionally striped structure comprising partitions 11 and stimuable phosphor-incorporated areas 12 which are alternately arranged side by side, as illustrated in Fig. 1. The cell structure, however, can be prepared in other forms with respect to the shapes and positions of the partitions. The stimuable phosphor sheet illustrated in Fig. 1 is advantageously scanned with stimulating rays in a direction traversing the striped partitions 11 and phosphor areas 12 when the radiation image is read out.

[0040] Figs. 4-(1), -(2) and -(3) show variations of the partitions. In Fig. 4-(1), the partitions 11 is two-dimensionally formed to give a grid partition. In Fig. 4-(2), a hexagonal stimuable phosphor-incorporated areas 12 are enclosed with a partition 11 to give a two dimensionally formed cells. In Fig. 4-(3), a circular stimuable phosphor-incorporated areas 12 are enclosed with a partition 11 to give a two dimensionally formed cells.

[0041] In Fig. 1, the top and bottom of the partition 11 are exposed over the surfaces of the stimuable phosphor sheet. However, the top and/or bottom of the partition 11 may be buried in the stimuable phosphor sheet. The partition preferably has a height corresponding to 1/3 to 1/1 of the thickness of the stimuable phosphor sheet.

[0042] The stimuable phosphor sheet of the invention can be prepared by the following process. The process is described for a stimuable phosphor sheet comprising stimuable phosphor-incorporated areas (composed of stimuable phosphor particles, voids, and binder) and partitions (composed of low light-absorbing fine particles, voids, and binder).

[0043] As the stimuable phosphor incorporated into the stimuable phosphor-incorporated areas, a phosphor giving a stimulated emission of a wavelength in the range of 300 to 500 nm when it is irradiated with stimulating rays of a wavelength in the range of 400 to 900 nm is preferably employed. In Japanese Patent Provisional Publications No. 2-193100 and No. 4-310900, some examples of the stimuable phosphors are described in detail. Examples of the preferred stimuable phosphors include divalent europium or cerium activated alkaline earth metal halide phosphors (e.g., BaFBr:Eu , BaFBr:Ce), and cerium activated oxyhalide phosphors.

[0044] Examples of the binders include natural polymers such as proteins (e.g., gelatin), polysaccharides (e.g., dextran) and gum arabic; and synthetic polymers such as polyvinyl butyral, polyvinyl acetate, nitrocellulose, ethyl cellulose, vinylidene chloride-vinyl chloride copolymer, polyalkyl (meth)acrylate, vinyl chloride-vinyl acetate copolymer, polyurethane, cellulose acetate butyrate, polyvinyl alcohol, linear polyester, and thermoplastic elastomers. These may be crosslinked with a cross-linking agent.

[0045] Examples of the solvents employable for preparing the phosphor dispersion include lower aliphatic alcohols such as methanol, ethanol, n-propanol and n-butanol; chlorinated hydrocarbons such as methylene chloride and ethylene chloride; ketones such as acetone, methyl ethyl ketone and methyl isobutyl ketone; esters of lower aliphatic alcohols with lower aliphatic acids such as methyl acetate, ethyl acetate and butyl acetate; ethers such as dioxane, ethylene glycol monoethyl ether, ethylene glycol monomethyl ether and tetrahydrofuran; and mixtures of the above-mentioned compounds.

[0046] The ratio between the binder and the phosphor in the phosphor dispersion depends on the characteristics of the stimuable phosphor and the desired property of the stimuable phosphor sheet, but generally they are incorporated at a ratio of 1:1 to 1:100 (binder:phosphor, by weight), preferably 1:8 to 1:40. The phosphor dispersion may further contain various additives such as dispersing agents (for assisting the phosphor particles in dispersing), plasticizers (for

increasing the bonding between the binder and the phosphor particles), anti-yellowing agents (for inhibiting yellowing of the phosphor layer), hardening agents, and/or crosslinking agents.

[0047] Examples of the low light-reflective fine particles are fine particles of inorganic materials such as aluminum oxide (i.e., alumina), yttrium oxide, gadolinium oxide, titanium dioxide, tellurium oxide. Certain stimutable phosphor particles may be employed as the low light-absorbing fine particles. Preferred are alumina particles. The low light-absorbing fine particles preferably have a mean particle diameter of 0.01 to 50 μm . The low light-absorbing fine particles preferably have a ratio of a refractive index K_1 of the fine particles to a refractive index K_a of voids, namely K_1/K_a , preferably is in the range of 1.1 to 3.0.

[0048] There are no specific limitation with respect to the polymer binder for production of the partitions, and the binders described hereinbefore for the production of the stimutable phosphor-incorporated area can be employed. In order to shorten the light-scattering length of the partition, a ratio of K_1 (i.e., refractive index of the low light-absorbing fine particles) to the refractive index of the polymer binder preferably is in the range of 1.1 to 3.0. Therefore, the polymer binder preferably is polyurethane, polyacrylate, polyethylene, or a fluororesin.

[0049] For the production of the partitions, a dispersion is prepared by mixing the low light-absorbing fine particles and the polymer binder in a solvent. The solvent may be chosen from those described hereinbefore for the preparation of a dispersion for producing the stimutable phosphor-incorporated area. The polymer binder and the low light-absorbing fine particles are mixed generally in a ratio of 1:80 to 1:3 (by weight), preferably 1:20 to 1:10 (by weight). The ratio can be varied depending on the desired characteristics of the target stimutable phosphor sheet and the nature of the low light-absorbing fine particles.

[0050] The stimutable phosphor sheet of the invention can be produced, for example, by the steps of beforehand preparing a sheet of partition material having a honeycomb structure composed of many hollows or holes, filling the hollows or holes with a dispersion of stimutable phosphor particles in a binder solution, and then drying the filled dispersion. The stimutable phosphor sheet of the invention can be also produced in the following manner. First, the low light-absorbing fine particles are dispersed in a thermosetting resin and processed to form a sheet of honeycomb structure. The honeycomb sheet is then pushed into a plastic stimutable phosphor sheet which is beforehand prepared. In the course of pushing the honeycomb sheet, the plastic stimutable phosphor sheet may be heated and/or pressed.

[0051] The stimutable phosphor sheet having a honeycomb structure can be also formed, for example, by lithography such as dry-etching process. Japanese Patent Provisional Publication No. 62-36599 describes a dry-etching process employable for the preparation of the stimutable phosphor sheet of the invention. Further, LIGA process and etching process using a laser (e.g., excimer laser) are also employable.

[0052] The stimutable phosphor sheet of the invention can be prepared from plural stimutable phosphor films and plural low light-absorbing fine particle-containing films by laminating and slicing process.

[0053] In more detail, a stimutable phosphor sheet of the invention having a grid partition can be produced by a process comprising the steps of:

- (i) producing plural stimutable phosphor films and plural partition films which contain a low light-absorbing fine particles;
- (ii) forming a multi-layered composite block in which the stimutable phosphor films and the partition films are alternately piled up under the condition that neighboring phosphor films and partition films would be placed in close contact with each other;
- (iii) repeatedly slicing the multi-layered composite block in the direction perpendicular to the plane of the piled films, to prepare plural striped phosphor films in which strips of the phosphor films and partition films are alternately arranged;
- (iv) forming another multi-layered composite block in which the striped phosphor films and the partition films are alternately piled up under the condition that neighboring striped films and partition films would be placed in close contact with each other; and
- (v) slicing repeatedly the multi-layered composite block formed in the step (iv) in the direction perpendicular to the plane of the piled films, so as to give the desired stimutable phosphor sheet.

[0054] A ratio of the volume of voids in the stimutable phosphor-incorporated area or in the partition can be adjusted to give the desired value, for instance, by appropriately compressing the stimutable phosphor sheet or the partition sheet by means of a calendaring treatment under heating.

[0055] The stimutable phosphor-incorporated area and the partition may not contain the polymer binder. In more detail, the partition film of honeycomb structure can be produced by sintering the low light-absorbing fine particles or deposition of low light-absorbing material. The stimutable phosphor-incorporated area can be produced by placing starting material of the stimutable phosphor in the honeycomb structure of the partition film and sintering the material of the stimutable phosphor in the honeycomb structure, or depositing the stimutable phosphor in the honeycomb structure of the partition film.

[0056] The stimuable phosphor-incorporated area may not contain voids, so long as it shows the specific light-scattering length and light-absorption length. The partition also may not contain voids and can consist essentially of low light-absorbing fine particles and a polymer binder. Otherwise, the voids are filled with a liquid organic material (liquid at room temperature) such as silicone oil or a fluorine atom-containing compound. The partition may further contain a stimuable phosphor so as to enhance the sensitivity of the stimuable phosphor sheet. The partition may be dyed with a coloring material absorbing the stimulating rays but not absorbing the stimulated emission, so as to increase the sharpness of the resulting radiation image. An appropriate coloring material is described, for instance, in Japanese Patent Publication No. 59-23400.

[0057] The stimuable phosphor sheet of the invention may have a support and a protective film, so as to keep the phosphor sheet from deterioration and to facilitate handling of the phosphor sheet. The stimuable phosphor sheet also can have a light-reflective layer on one surface side (or between the phosphor sheet and the support, if the support is provided), so as to increase the sensitivity of the phosphor sheet.

[0058] In Fig. 5-(1), the stimuable phosphor sheet of Fig. 1-(1) is provided on its lower side with a support 19 and a light-reflective layer 20 and on its upper side with a protective layer 21. In Fig. 5-(2), the stimuable phosphor sheet is provided on its lower side with a transparent support 19' and on its upper side with a protective layer 21. The stimuable phosphor sheet of Fig. 5-(2) is favorably employable in the known double side-reading system in which the stimulated emission is collected from the both surface sides of the phosphor sheet. In Fig. 5-(3), the stimuable phosphor sheet is provided on its lower side with a support 19 and a light-reflective layer 20 and on its upper side with a protective layer 21. The tops of the partitions are buried in the stimuable phosphor sheet 10.

[0059] As the support, a sheet or a film of flexible resin material having a thickness of 50 μm to 1 μm is generally employed. The support may be transparent or may contain light-reflecting material (e.g., alumina particles, titanium dioxide particles, and barium sulfate particles) or voids, for reflecting the stimulating rays or the stimulated emission. Further, it may contain light-absorbing material (e.g., carbon black) for absorbing the stimulating rays or the stimulated emission. Examples of the resin materials include polyethylene terephthalate, polyethylene naphthalate, aramid resin and polyimide resin. The support may be a sheet of other material such as metal, ceramics and glass, if needed. On the phosphor sheet-side surface of the support, auxiliary layers (e.g., light-reflecting layer, light-absorbing layer, adhesive layer, electroconductive layer) or many hollows may be provided. On the other side surface, a friction-reducing layer or an anti-scratch layer may be formed.

[0060] On the surface not facing the support, the stimuable phosphor sheet may have a protective film. In order not to affect the stimulating rays or the stimulated emission, the protective film preferably is transparent. Further, for efficiently protecting the stimuable phosphor sheet from chemical deterioration and physical damage, the protective film should be both chemically stable and physically strong.

[0061] The protective film can be provided by fixing a beforehand prepared transparent plastic film (e.g., polyethylene terephthalate) on the stimuable phosphor sheet with adhesive, or by coating the phosphor sheet with a solution of protective film material and drying the coated solution. Into the protective film, fillers of fine particles may be incorporated so as to reduce blotches caused by interference and to improve the quality of the resultant radiation image. The thickness of the protective film generally is in the range of approx. 0.1 to 20 μm .

[0062] For enhancing the resistance to staining, a fluororesin layer is preferably provided on the protective film. The fluororesin layer can be formed by coating the surface of the protective film with a solution of a fluororesin in an organic solvent, and drying the coated solution. The fluororesin may be used singly, but generally a mixture of the fluororesin and a film-forming resin is employed. In the mixture, an oligomer having polysiloxane structure or perfluoroalkyl group can be further added. The coating can be performed using known coating means such as doctor blade, roll coater, and knife coater. Into the fluororesin layer, a filler of fine particles may be incorporated so as to reduce blotches caused by interference and to improve quality of the resultant radiation image. The thickness of fluororesin layer generally is in the range of 0.5 to 20 μm . In the formation of the fluororesin layer, additives such as a crosslinking agent, a film-hardening agent and an anti-yellowing agent can be used. In particular, the crosslinking agent advantageously improves durability of the fluororesin layer.

[0063] The light-reflective layer can comprise a white pigment such as alumina pigment, titanium dioxide pigment, or a barium sulfate pigment, or phosphor particles giving no stimulated emission. In the light-reflective layer, the pigment or particles are dispersed and supported in a binder.

[0064] The present invention is further described by the following examples.

[Example 1]

1) Preparation of stimuable phosphor sheets for stimuable phosphor-incorporated area

[0065] Particles of stimuable phosphor (BaFBr:Eu , particle sizes: 5 μm) and a thermoplastic high molecular weight-polyester resin (binder) were dispersed in methyl ethyl ketone in a weight ratio of 5:1, to prepare a phosphor dis-

persion having a viscosity of 30 PS (at 25°C). The phosphor dispersion was then coated on a temporary support having a releasing surface by means of a coating apparatus, and dried to give a dry phosphor layer. The phosphor layer thus formed was then peeled from the temporary support to give a stimuable phosphor film. The stimuable phosphor film was compressed under heating by means of a calendaring apparatus to reduce its void volume.

[0066] The above-mentioned preparatory procedures were repeated to prepare various stimuable phosphor sheets (volume of phosphor: 52%, void volume: 3%, thickness: approx. 20 to 100 μm) for the production of stimuable phosphor-incorporated areas.

2) Preparation of partition films

[0067] Alumina fine particles (particle size: 1.0 μm) and a high molecular weight-acryl resin were dispersed in methyl ethyl ketone in a weight ratio of 15:1, to prepare a alumina dispersion having a viscosity of 30 PS (at 25°C). The alumina dispersion was coated on a temporary support having a releasing surface by means of a coating apparatus, and dried to give a dry alumina-containing layer. The alumina-containing layer thus formed was then peeled from the temporary support to give an alumina-containing film.

[0068] The above-mentioned preparatory procedures were repeated to prepare various alumina-containing films (volume of alumina particles: 51%, void volume: 38%, ratio of refractive index (alumina particles/void): 1.67, thickness: approx. 10 to 30 μm) for the production of partitions.

3) Preparation of stimuable phosphor sheets

[0069] Each of the stimuable phosphor film (thickness: 100 μm) and the alumina-containing film (thickness: 10 μm) was cut to give square pieces (40 mm x 40 mm). Thus prepared pieces of the stimuable phosphor films and the alumina-containing films were alternately piled up to form a multi-layered composite consisting of 360 layers. The composite was then heated under pressure to produce a multi-layered composite block. The multi-layered composite block was repeatedly sliced in a direction perpendicular to the layer plane with a wide microtome, to produce stimuable phosphor sheets having one-dimensionally striped phosphor cell structure (thickness: 200 to 1,000 μm).

5) Preparations of other stimuable phosphor sheets

[0070] The above-mentioned procedures were repeated except for replacing the partition film of 20 μm thick with a partition film of 30 μm , to produce stimuable phosphor sheets of striped phosphor cell structure (thickness: 200 to 1,000 μm).

[Comparison Example 1]

[0071] The procedures of Example 1 for the preparation of a phosphor sheet were repeated except for changing the weight ratio of the stimuable phosphor to binder to 20/1, to prepare a phosphor dispersion for preparing a stimuable phosphor sheet. The phosphor dispersion was coated on a temporary support having a releasing surface by means of a coating apparatus, and dried to give a dry phosphor layer. The phosphor layer was then peeled from the temporary support to give a stimuable phosphor film. The stimuable phosphor film was compressed under heating by means of a calendaring apparatus to give a stimuable phosphor sheet having no cell structure (thickness: 200 to 1,000 μm).

[Comparison Example 2]

[0072] The procedures of Example 1 were repeated except for replacing the alumina-containing partition film with a polyethylene terephthalate film (thickness: 6 μm) on which aluminum metal was vacuum-deposited to prepare various stimuable phosphor sheets having a one-dimensionally striped phosphor cell structure (thickness: 200 to 1,000 μm).

[Examples 2 to 9]

[0073] The procedures of Example 1 for the preparation of a stimuable phosphor sheet were repeated except for changing the weight ratio of the stimuable phosphor to binder as set forth in Table 1. Further, the procedures of Example 1 for the preparation of a partition film were repeated except for changing the weight ratio of the alumina fine particles to the acryl resin as set forth in Table 1.

[0074] Thus, there were prepared various stimuable phosphor sheets having a one-dimensionally striped phosphor cell structure (thickness: 200 to 1,000 μm).

[Comparison Examples 3 to 6]

[0075] The procedures of Example 1 for the preparation of a stimuable phosphor sheet were repeated except for changing the weight ratio of the stimuable phosphor to binder as set forth in Table 1. Further, the procedures of Example 1 for the preparation of a partition film were repeated except for changing the weight ratio of the alumina fine particles to the acryl resin as set forth in Table 1.

[0076] Thus, there were prepared various stimuable phosphor sheets having a one-dimensionally striped phosphor cell structure (thickness: 200 to 1,000 μm).

[Example 10]

[0077] Plural partition films (thickness: 10 μm) and a multi-layered composite block were prepared in the manner as described in Example 1. The composite block was repeatedly sliced by means of a wide microtome to produce plural stimuable phosphor sheets of one-dimensionally striped phosphor cell structure (thickness: 100 μm). Thus prepared stimuable phosphor sheets and the partition films were alternately piled up to form a multi-layered composite consisting of 200 layers. The composite was then heated under pressure to produce a multi-layered composite block. Thus produced multi-layered composite block was repeatedly sliced by means of a wide microtome, to produce stimuable phosphor sheets having a one-dimensionally striped phosphor cell structure (thickness: 200 μm , 600 μm , 1,000 μm).

[0078] The procedures of Example 1 for the preparation of a phosphor sheet were repeated except for changing the weight ratio of the stimuable phosphor to binder as set forth in Table 1. Further, the procedures of Example 1 for the preparation of a partition film were repeated except for changing the weight ratio of the alumina fine particles to the acryl resin as set forth in Table 1.

[0079] Thus, there were prepared various stimuable phosphor sheets having a one-dimensionally striped phosphor cell structure (thickness: 200 to 1,000 μm).

[Evaluation of Stimuable Phosphor Sheet]

[0080] Each of various stimuable phosphor sheets for preparing the stimuable phosphor-incorporated area and various partition films was spectroscopically measured in its transmittance at a wavelength of 600 nm (i.e., wavelength of typical stimulating rays) as well as at a wavelength of 400 nm (i.e., wavelength of typical stimulated emission). The measured transmittance was incorporated into the aforementioned equation (3) according to the Kubeluka-Munk theory to calculate the light-scattering length and the light-absorption length. The light-absorption length of the stimuable phosphor-incorporated area and the partition of the stimuable phosphor sheets of Examples 1 to 10 was more than 1,000 μm . Other results are set forth in Tables 1 and 2, in which "scat." stands for "scattering".

[0081] Each of the stimuable phosphor sheets of Examples 1 to 10 and Comparison Examples 1 to 6 was exposed to X-rays of 80 kVp (dosage: 10 mR) and scanned with He-Ne laser beam. The stimulated emission was then detected to evaluate the sensitivity from the luminance of stimulated emission. Further, the sharpness (CTF at 2 lp) was obtained from the resulting image data for evaluating the image quality. The results are graphically illustrated in Figs. 6 to 9.

Table 1

	Phosphor /Binder (weight ratio)	Phosphor-incorporated area		Alumina /resin (weight ratio)	Partition	
		scat.	width		scat.	width
Example 1	5/1	66 μm	100 μm	15/1	4 μm	10 μm
Example 1	5/1	66 μm	100 μm	15/1	4 μm	20 μm
Example 1	5/1	66 μm	100 μm	15/1	4 μm	30 μm
Example 2	10/1	20 μm	100 μm	15/1	4 μm	30 μm
Example 3	7/1	40 μm	100 μm	15/1	4 μm	30 μm
Example 4	5/1	66 μm	100 μm	7/1	15 μm	10 μm
Example 5	5/1	66 μm	100 μm	7/1	15 μm	20 μm
Example 6	5/1	66 μm	100 μm	7/1	15 μm	30 μm
Example 7	5/1	66 μm	100 μm	5/1	20 μm	10 μm

Table 1 (continued)

	Phosphor /Binder (weight ratio)	Phosphor-incorporated area		Alumina /resin (weight ratio)	Partition	
		scat.	width		scat.	width
Example 8	5/1	66 μm	100 μm	5/1	20 μm	20 μm
Example 9	5/1	66 μm	100 μm	5/1	20 μm	30 μm
Example 10	5/1	66 μm	100 μm	15/1	4 μm	10 μm
Com.Ex. 1	20/1	11 μm	—	—	—	—
Com.Ex. 2	5/1	66 μm	100 μm	—	—	6 μm
Com.Ex. 3	20/1	11 μm	100 μm	15/1	4 μm	30 μm
Com.Ex. 4	5/1	66 μm	100 μm	4/1	25 μm	10 μm
Com.Ex. 5	5/1	66 μm	100 μm	4/1	25 μm	20 μm
Com.Ex. 6	5/1	66 μm	100 μm	4/1	25 μm	30 μm

[0082] Fig. 6 graphically indicates a relationship between the thickness of the stimuable phosphor sheet and the luminance of the stimulated emission (in terms of relative value) in the stimuable phosphor sheets of Example 1 and Comparison Examples 1 and 2, under the condition that the partition has a width of 30 μm . In the graph, the square marks are for Example 1, the circular marks are for Comparison Example 1, and the triangle marks are for Comparison Example 2.

[0083] Fig. 7 graphically indicates a relationship between the thickness of the stimuable phosphor sheet and the sharpness (2 lp · CTF) in the stimuable phosphor sheets of Example 1 and Comparison Example 1, under the condition that the partition has a width of 30 μm . In the graph, the square marks are for Example 1 and the circular marks are for Comparison Example 1.

[0084] Fig. 8 graphically indicates a relationship between the light-scattering length of the partition and the sharpness (2 lp · CTF) in the stimuable phosphor sheets of Examples 1 to 9 and Comparison Examples 4 to 6, under the condition that the stimuable phosphor-incorporated area has a light-scattering length of 66 μm and the stimuable phosphor sheet has a thickness of 400 μm .

[0085] Fig. 9 graphically indicates a relationship between the light-scattering length of the stimuable phosphor-incorporated area and the luminance of the stimulated emission (in terms of relative value) in the stimuable phosphor sheets of Examples 1 to 9 and Comparison Example 3, under the condition that the partition has a light-scattering length of 4 μm and a width of 30 μm , and the stimuable phosphor sheet has a thickness of 1,000 μm .

[0086] The results illustrated in Fig. 6 indicate that the conventional stimuable phosphor sheet (Comparison Example 1) having no cell structure has a high density of the phosphor and shows a short light-scattering length, but that although this phosphor sheet shows a relatively high luminance of the stimulated emission when the thickness of the phosphor sheet is small, the luminance does not proportionally increase with the increase of the thickness of the phosphor sheet. The known stimuable phosphor sheet (Comparison Example 2) having a cell structure shows a light-absorption of approx. 15 to 20% because the partition having a mirror surface is made of metallic material. The luminance of the stimulated emission detected from the stimuable phosphor sheet of Comparison Example 2 is low regardless of variation of the thickness of the stimuable phosphor sheet.

[0087] In contrast, the stimuable phosphor sheet (Example 1) according to the invention shows a low density value of stimuable phosphor particles due to the presence of the partition, and gives the stimulated emission at a low luminance when the thickness of the stimuable phosphor sheet is small. However, when the thickness of the phosphor sheet is increased, the luminance increases almost proportionally. This is because the stimuable phosphor-incorporated area shows a long light-scattering length, and hence the stimulating rays can reach the deep portion of the phosphor-incorporated area even when the thickness of the phosphor sheet increases, and the stimulated emission is efficiently recovered. Further, the extreme long light-absorption length of the partition serves to extremely reduce absorption of the stimulated emission by the partition.

[0088] Fig. 7 indicates that the stimuable phosphor sheet of the invention (Example 1) gives a radiation image of high sharpness which is less decreased when the thickness of the phosphor sheet is increased, as compared with the conventional stimuable phosphor sheet having no cell structure (Comparison Example 1). In the stimuable phosphor sheet of the invention, the partition having a short light-scattering length keeps the stimulating rays from diffusing on the plane of the phosphor sheet.

[0089] Fig. 8 indicates that a partition having a longer light-scattering length is less effective to keep the stimulating

rays from diffusing on the plane of the phosphor sheet and hence decreases the sharpness of the resulting radiation image.

[0090] Fig. 9 indicates that the luminance of the stimulated emission increases when the light-scattering length of the stimuable phosphor-incorporated area increases in the case that the stimuable phosphor sheet has a thickness as much as 1,000 μm . This is because that the stimulating rays reach the deep portion of the stimuable phosphor-incorporated area to increase the amount of stimulated emission and the stimulated emission is well recovered.

[Example 11]

[0091] A stimuable phosphor sheet having a cell structure (thickness: 600 μm , width of partition : 30 μm) was prepared in the same manner as described in Example 1, except that the alumina fine particles (diameter: 1.0 μm), BaFBr : Eu phosphor particles (diameter: 5.0 μm), and a high molecular weight-acrylate resin in a ratio of 7.5/7.5/1 (by weight) were added to methyl ethyl ketone.

[0092] Thus prepared stimuable phosphor sheet was measured in the same manner to give a light-scattering length of 6 μm and a light-absorption length of more than 1,000 μm . The luminance of the stimulated emission and the sharpness (in terms of CTF) were measured in the same manner. The stimuable phosphor sheet having a partition containing stimuable phosphor particles shows a high luminance of the stimulated emission which increases by 9% in comparison with the stimuable phosphor sheet of Example 1, while shows a decrease of CTF by 3%.

[0093] The above-mentioned results suggest that the sensitivity of a stimuable phosphor sheet having a cell structure is remarkably increased with slight decrease of the sharpness by incorporating a stimuable phosphor into the partition.

[Example 12]

[0094] A stimuable phosphor sheet having a cell structure (thickness: 600 μm , width of partition : 10 μm) was prepared in the same manner as described in Example 1, except that the partition sheet was prepared by adding 500 mg of ultramarine to 100 g of alumina fine particles.

[0095] Thus prepared stimuable phosphor sheet shows a sharpness (in terms of CTF) higher than that of the stimuable phosphor sheet of Example 1 by 10%, while the decrease of the luminance of the stimulated emission is 6%.

[0096] The above-mentioned results suggest that the sharpness can be increased with little decrease of the sensitivity, by coloring the partition with a dye which absorbs the stimulating rays but does not absorb the stimulated emission.

Claims

1. A stimuable phosphor sheet for a radiation image recording and reproducing method comprising the steps of recording a radiation image as a latent image, irradiating the latent image with stimulating rays to release stimulated emission, and electrically processing the emission to reproduce the radiation image, comprising partitions that divide the phosphor sheet on its plane to give plural sections, and stimuable phosphor-incorporated areas placed in the sections wherein the stimuable phosphor-incorporated areas have a light-scattering length of 20 to 100 μm and a light-absorption length of 1,000 μm or longer, while the partitions have a light-scattering length of 0.05 to 20 μm and a light-absorption length of 1,000 μm or longer, under the condition that a ratio of the light-scattering length of the stimuable phosphor-incorporated areas to that of the partitions is 3.0 or more.
2. The stimuable phosphor sheet of claim 1, wherein the stimuable phosphor-incorporated areas comprise stimuable phosphor particles and a binder.
3. The stimuable phosphor sheet of claim 2, wherein the stimuable phosphor particles have a volume in the range of 40% to 95% of the phosphor-incorporated area, and the phosphor-incorporated areas have a void volume of 0 to 20%.
4. The stimuable phosphor sheet of claim 1, wherein the partitions comprise low light-absorbing fine particles and a binder.
5. The stimuable phosphor sheet of claim 4, wherein the low light-absorbing fine particles have a volume in the range of 30% to 90% of the partition.
6. The stimuable phosphor sheet of claim 4, wherein the low light-absorbing fine particles have a particle size of 0.01

to 5.0 μm .

7. The stimable phosphor sheet of claim 4, wherein the low light-absorbing fine particles are fine particles of alumina.

8. The stimable phosphor sheet of claim 4, wherein the partitions further comprise voids.

9. The stimable phosphor sheet of claim 4, wherein the partitions further comprise voids in a volume of 10% to 70%.

10. The stimable phosphor sheet of claim 8, wherein a ratio of refractive index of the low light-absorbing fine particles to that of the voids is in the range of 1.1 to 3.0.

11. The stimable phosphor sheet of claim 4, wherein the partitions further comprise stimable phosphor particles.

12. The stimable phosphor sheet of claim 4, wherein the partitions are dyed with a coloring material which absorbs the stimulating rays, while absorbs no stimulated emission.

13. The stimable phosphor sheet of claim 4, which has a thickness in the range of 50 to 1,500 μm .

14. A radiation image recording and reproducing method comprising the steps of recording on a stimable phosphor sheet a radiation image as a latent image, irradiating the latent image with stimulating rays to release stimulated emission, and electrically processing the emission to reproduce the radiation image, the stimable phosphor sheet comprising partitions that divide the phosphor sheet on its plane to give plural sections, and stimable phosphor-incorporated areas placed in the sections, wherein the stimable phosphor-incorporated areas have a light-scattering length of 20 to 100 μm and a light-absorption length of 1,000 μm or longer, while the partitions have a light-scattering length of 0.05 to 20 μm and a light-absorption length of 1,000 μm or longer, under the condition that the ratio of the light-scattering length of the stimable phosphor-incorporated areas to that of the partitions is 3.0 or more.

FIG. 1

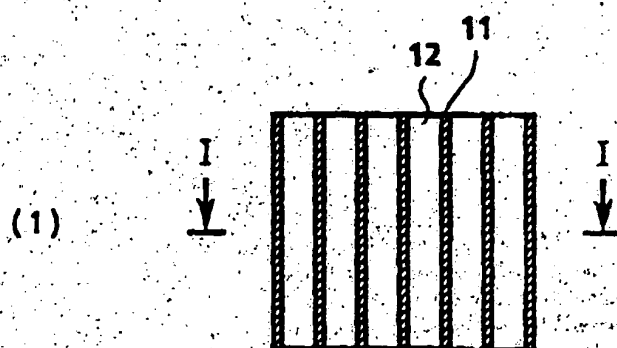


FIG. 2

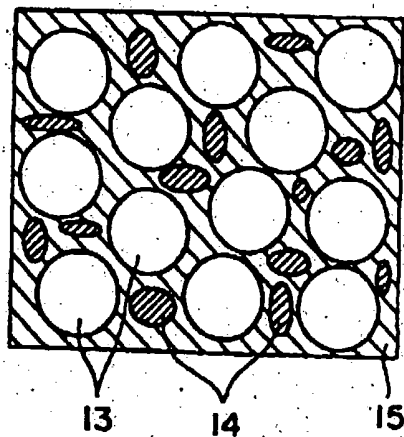


FIG. 3

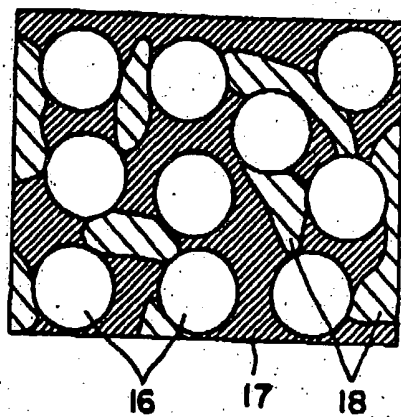


FIG. 4

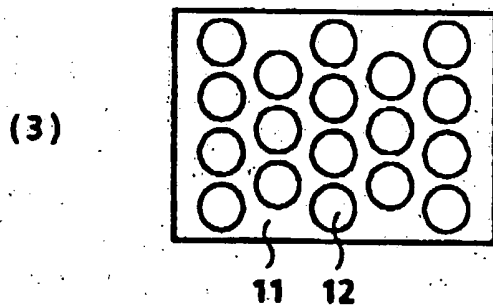
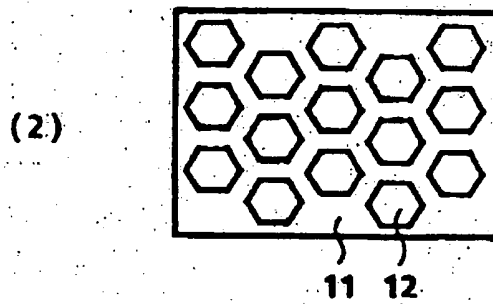
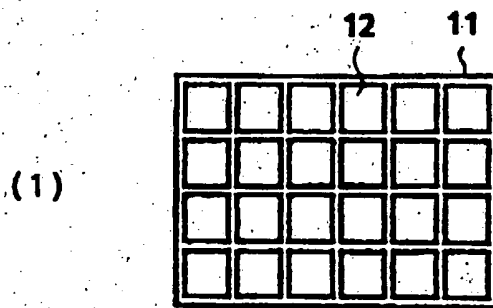


FIG. 5

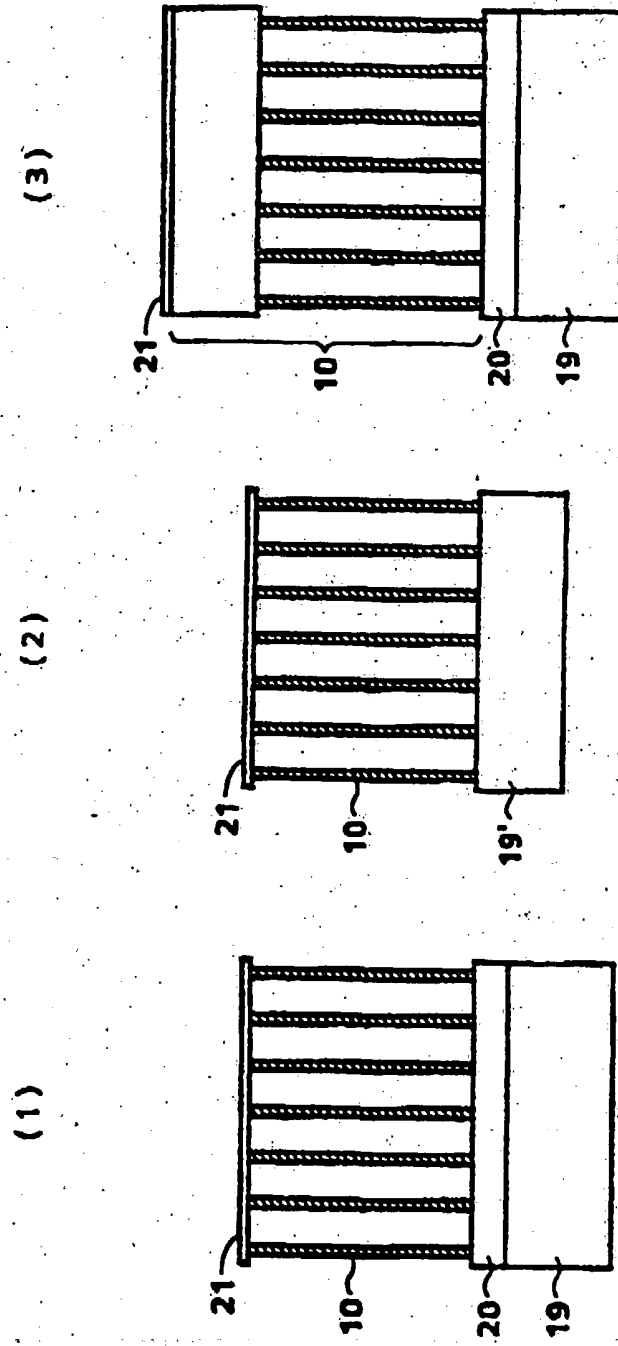


FIG. 6

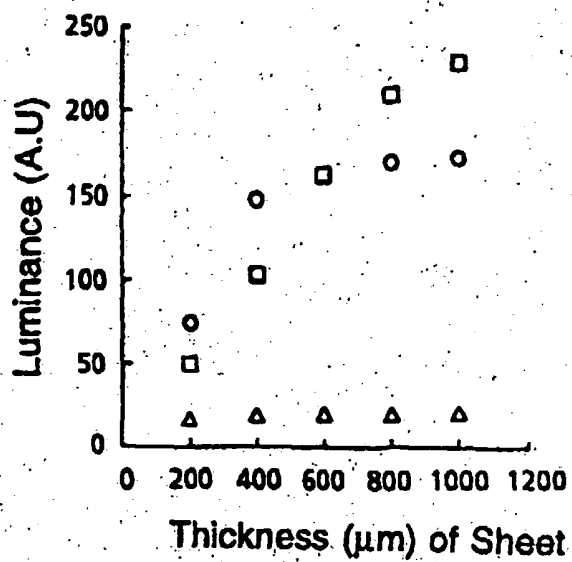


FIG. 7

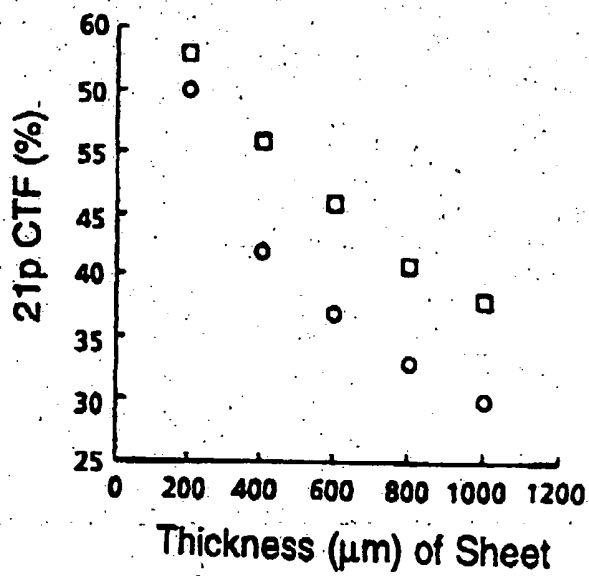


FIG. 8

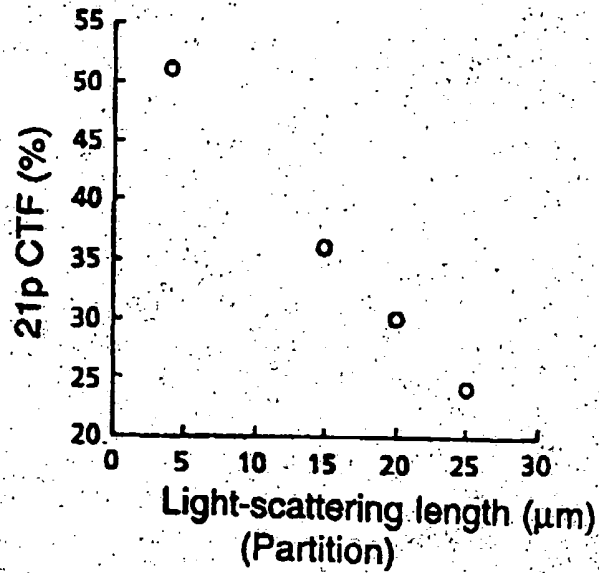


FIG. 9

